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APPLICATIONS OF OR IN DISASTER RELIEF OPERATIONS

Impact of internet of things (IoT) in disaster management: a task-technology fit perspective

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Abstract Disaster management aims to mitigate the potential damage from the disasters, ensure immediate and suitable assistance to the victims, and attain effective and rapid recovery. These objectives require a planned and effective rescue operation post such disasters. Different types of information about the impact of the disaster are, hence, required for planning an effective and immediate relief operation. The IoT technology available today is quite mature and has the potential to be very useful in disaster situations. This paper analyzes the requirements for planning rescue operation for such natural disasters and proposes an IoT based solution to cater the identified requirements. The proposed solution is further validated using the task-technology fit (TTF) approach for analyzing the significance of the adoption of IoT technology for disaster management. Results from the exploratory study established the core dimensions of the task requirements and the TTF constructs. Results from the confirmatory factor analysis using PLS path modelling, further, suggest that both task requirements and

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IoT technology have significant impact on the IoT TTF in the disaster management scenario. This paper makes significant contributions in the development of appropriate constructs for modeling TTF for IoT Technology in the context of disaster management.

Keywords Task-technology fit · Disaster management · Internet of things · IoT · TTF · Strategic value

1 Introduction

Disasters cannot be predicted but the least that one can do is to be prepared for it. Relief operations after disaster is much different and challenging when compared to aiding distributions done by the government agencies under normal circumstances. Further, training by simulating disaster situations is almost impossible due to the scale and magnitude of natural disasters. Technology has its own limitations but has the potential to aid in relief operations planning, management and analysis of after-effects for long term disaster management (Dai et al. 1994; Papadopoulos et al. 2017; Simon 1997). The IoT technology available today is quite mature and has the potential to be very useful in disaster situations. Disaster management planning depends heavily on the topology, climatic conditions, habitat etc. of the area as well as on the available resources of the machinery. Duhamel et al. (2016) proposed the heuristics of operations research and management science to optimize the resilience in the relief operations considering the impact of the distribution of the relief resources on the population.

Manpower deployed during disaster management may be trained but they must be provided with vital information in time for proper and prompt utilization. This is required to reduce the much needed response time for relief operations. Timely dispatch of relief supplies from distribution centers to hospitals in coordination with the schedule of the medical teams is also a critical activity in disaster management (Lee et al. 2006; Lei et al. 2015). Hence, it is a requirement that proper planning must be done in country specific context involving different stakeholders for an effective and efficient disaster management.

The society, in general, must be trained to handle and help each other in case of natural disaster scenarios. Government agencies are spending money for creating awareness by advertisements etc. However, these are mostly without any feedback from common masses and hence, there is sufficient room for increasing the effectiveness of government efforts if inputs from various sections of society are taken and incorporated in proper planning of preparedness and relief operations. Inputs from the society in combination with the use of IoT technology can help in proper planning to handle disaster management in Indian context.

Although some works (Dai et al. 1994; Yang et al. 2013) exist in the literature that examine the usefulness of IoT in disaster management, they are not in Indian context. Disaster management scenario in foreign countries is completely different than that of India. Hence, there is a need to identify and prioritize the information required for efficient management of relief operations in case of natural calamities. This paper addresses the task requirements for the personnel involved in the disaster management operations. The paper, further, proposes an Internet of Things (IoT) solution for an efficient disaster management. The proposed solution is validated using the task-technology fit approach, thereby analyzing the strategic value derived by using the proposed solution for disaster management operations. This work shall lay the foundation of the technical solutions that can be further implemented for realizing the benefits of IoT in disaster management.

The rest of the paper is organised as follows: Sect. 2 reviews the available literature pertaining to disaster management, IoT technology and the existing TTF model, Sect. 3 outlines the disaster management scenario in Indian context, Sect. 4 provides the details of the different phases of the research, Sect. 5 highlights the development, measurement scales and characteristics of the target population employed for the evaluation of the proposed technical IoT infrastructure. Section 6 analyzes the obtained results. Furthermore, Sect. 7 discusses the important research findings. Finally, Sect. 8 presents the concluding remarks and future work.

2 Literature review

This section presents an overview of the existing literature relevant to the research presented in this paper. The role of the technology in disaster management that has been examined to investigate IoT can assist the personnel involved in relief operations post any natural disaster. We further provide a brief discussion of the TTF model that has been adopted for validating the outcome of this research.

2.1 Role of technology in disaster management

There is a substantial literature available regarding the field studies about the emergency relief operations (Jiang et al. 2004). The methodology adopted by these studies includes the observations of training exercises, first-hand experience of real incidents, conducting interviews, and recursive refinement of initial prototypes. Kyng et al. (2006) identified challenges related to victims, experts, and IT in developing intelligent systems for immediate relief response. The study focused upon designing a solution for identifying and monitoring patients in emergency scenario. The authors formulated the design paradigm to address the identified challenges and analyzed different prototypes to propose guidelines for the realization of such systems. Victim related challenges call for medical equipment communicating over wireless medium, e.g., wireless bio-monitoring system. The challenges concerning the experts led to the development of a real-time video model for providing situational awareness with the use of video camera, GPS and digital compass. IT related challenges indicate that the devices developed for managing emergency responses should also be employed for daily tasks, else the experts may fail to utilize them effectively.

Kristensen (2006) emphasized upon the use of participatory design in the emergency medical service. This is an inclusive and a recursive process that involves the practitioners and researchers for designing and evaluating a system. This work led to the formulation of a set of designs for supporting emergency medical services. Two of the proposed designs regarding remote access display and wireless bio-monitors are significant for our work. The main concerns of these paradigms are to enable remote access to the data collected by various sensors and infer situational awareness regarding the victims and the available relief resources. Jiang et al. (2004) recognized the following design issues in the context of emergency relief services, assessment of the situation through multiple sources of information, resource allocation, accountability of resources and personnel and communication support. The authors proposed a conceptual prototype for addressing the identified design issues. Their work deduced the following observations: first, in case of disasters, the activities should be focused upon the people and the surrounding environment; and second, redundancy is a crucial design principle for improving the reliability of the communication and providing efficient safety.

Several studies in the available literature have considered the significance of proper awareness of the situation and apt decision-support systems for managing emergency situations in case of disasters (Anparasan and Lejeune 2017). This urged the attention towards the development of emergency-response information systems (EISs). EIS should be able to provide adequate situational awareness to the first responders for better planning of the relief operation. The decision-making failures of the humans during the disastrous events of Bhopal (Endsley 1999) and the deaths of the rescue personnel during 9/11 (Son et al. 2007) can be attributed to the lack of situational awareness and intelligent decision-support systems. Dai et al. (1994) explored the significance of computerized support systems for emergency decision making. A number of research studies in the context of EIS development have considered the significance of enhancing the situational awareness of the first responder situational awareness for improving their capability of making apt decisions. Important studies (Dai et al. 1994), which proposed technical models for emergency relief response, have emphasized upon the ability of the information support to provide an insight into the situation faced by the responders for designing an effective EIS. However, such systems do not require only static information such as the information system for office use. These EISs are designed to work in an extreme dynamic environment and hence require real-time information about the disaster impacts and the locations of the personnel and resources employed for the relief operations.

2.2 Internet of things (IoT)

The term ‘Internet of Things’ (IoT) was coined by Kevin Ashton in 1998 in his talk for Auto-ID Center at the Massachusetts Institute of Technology (MIT). However, it was formally introduced by the International Telecommunication Union (ITU) in the ITU Internet report in 2005 (ITU 2005). Semantically, IoT refers to a world-wide network of interconnected objects having unique identity and communicating using standard protocols (INFSO 2008). The ‘things’ in such a network refers to any virtual or real entity such as human beings, inanimate objects, intelligent software agents or even virtual data. The paradigm of IoT can be envisaged in conjunction with effective data collection strategies and the ability to share such data. The technology has adequate potential to realize complex decision support systems by delivering the required services in a more precise, organized and intelligent manner (Xu et al. 2014; Gershenfeld et al. 2004; Gubbi et al. 2013).

The European Commission in its research roadmap has envisioned the IoT as an indispensable component of the future Internet (European Commission 2008). Gershenfeld et al. (2004) refer to IoT as an add-on of the Internet to extend the coverage to the physical entities that can only support low-power computations. Fleisch (2010), however, debates that the IoT is a service provided by the Internet as any other existing web services. From the very onset of the conceptualization of IoT in 2005, the development of smart objects having sensing, communication and actuating capabilities have seen an accelerated growth. Such network-enabled smart objects have numerous applications in the areas of environment monitoring (Llic et al. 2009), healthcare (Niyato et al. 2009; Oztekin et al. 2010; Thompson and Hagstrom 2008), transportation and logistics (Broll et al. 2009), social networks (Sinha and Kumar 2016), smart buildings (Darianian and Michael 2008) etc. The applications of this new paradigm significantly rely upon the data gathered by the distributed smart objects and the communication infrastructure for the transmission of data. In the context of disaster management, IoT has the potential to become one of the enabling technologies. The key application areas include:

1. Disaster risk minimization and prevention: Monitoring disaster possibilities through satellite communication and geographic information system (GIS), designing early warning systems, use of social media for awareness creation.
2. Emergency response: Real-time communication for timely relief and response measures.
3. Disaster recovery: Online missing person search and fund management systems.

The dynamic nature of the requirements and environment during a relief operation emphasizes upon the ability to make efficient and precise decisions in minimal time. The IoT technology, having the potential for communicating instantaneous information updates, can be a key player for realizing dynamic workflow adaptations. Wang et al. (2008) proposed WIFA for assessing and managing the workflow dynamically. The work was further improved in the research of Wang et al. (2009) by incorporating awareness about the status of the resource in terms of requirement and availability. Wang et al. (2008) developed an intelligent user interface for an efficient management of the activities involved in disaster management. Fosso Wamba et al. (2016) developed a conceptual model to identify the determinants of Radio Frequency Identification (RFID) in small and mid-sized enterprises.

The existing literature have not explicitly analyzed the significance of IoT as a comprehensive technology for relief operations. Yang et al. (2013) introduced the concept of employing IoT technology in the emergency management scenario. The work, however, lacks statistical analysis of the proposed constructs and qualitative tests of the proposed hypothesis. The main objective of our work is to obtain valuable insight into the workflow of the rescue operations post any natural disaster, what type of information is required, how IoT can cater these task requirements, and how the adoption of IoT can provide long-term strategic values. The paper specifically focuses upon how the adoption of IoT technology can enhance the relief operations in disaster management.

2.3 Task-technology fit (TTF)

Goodhue and Thompson (1995) developed the TTF approach for understanding the collaboration between individual performance and information systems. Figure 1 illustrates a basic model of TTF. Here, task characteristics denote the activities performed by the individuals, while technology characteristics implies the technology utilized by the individuals for performing the required tasks. Task-technology fit, hence, can be defined as the extent to which a technology catalyzes the activities of an individual for performing the required tasks. One significant focus of TTF has been on individuals to assess and explain information systems success and impact on individual performance. TTF has been mainly considered for assessing the success of information systems and examining its impact on the individual performance. Performance impacts refer to the accomplishment of a set of tasks by an individual. Greater performance indicates the amalgamation of increased efficiency, improved effectiveness and better quality.

TTF can, thus, provide the guidance for developing a technology to effectively cater the task requirements. TTF analyzes the relationship between the tasks and technology fit by estimating user performance and technology utilization.

3 Disaster management scenario in India

The workflow for disaster management in India is not similar to the approaches adopted by the other countries of the world. It is a well-established fact that the rescue operation requires

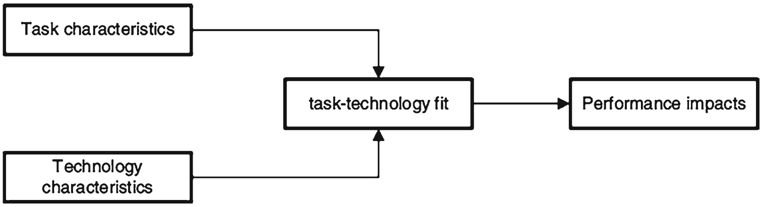

Fig. 1 Task-technology fit model (*Source*: Goodhue and Thompson 1995)

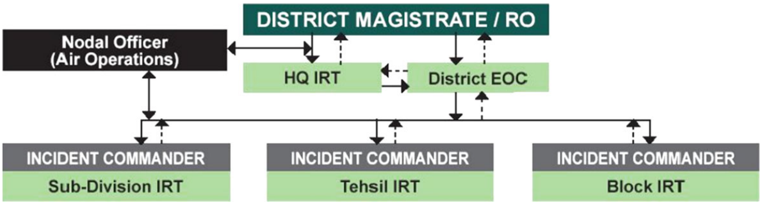

Fig. 2 Disaster response structure at district level (*Source*: NDMG 2010)

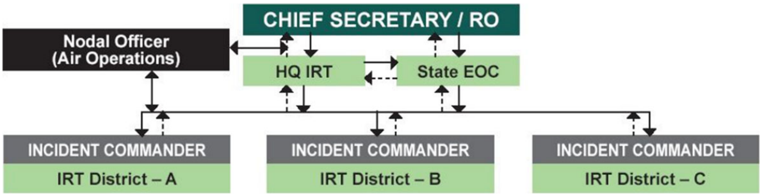

Fig. 3 Disaster response structure at state level (*Source*: NDMG 2010)

an efficient collaboration of the local communities with the government officials and other organizations involved in the disaster management. The community dynamics in a country like India is quite complex. The disaster management manuals available on the web clearly depict the complex picture of the co-ordination of rescue personnel at different levels in India. Figures 2 and 3 outline the co-ordination of responses at various levels.

The Government of India ordained the Disaster Management Act in December 2005, which envisaged the formulation of National Disaster Management Authority (NDMA) and State Disaster Management Authorities (SDMAs) to spearhead and implement a holistic and integrated approach for disaster management in India. Manufacturers' Association for Information Technology (MAIT)—an IT industry association, which works in close coordination with the Government of India to strategies for Digital India, submitted a whitepaper in 2016 (Digital India Action Group 2016) with the aim to create an awareness about the potential uses of IoT in disaster management in India and to cover some of the requirements, issues and challenges related to IoT applications for disaster management. The whitepaper also discusses about a number of initiatives that have been taken by the central and state governments in the area of disaster management. A national disaster management framework has been developed by the ministry of home affairs. The framework comprehensively covers all aspects of disaster management including the institutional mechanism, disaster prevention, legal and policy framework, early warning systems, disaster preparedness and human resource development. United Nations Development Program (UNDP) has also joined hands in this effort of government of India and is implementing GoI-UNDP disaster risk man-

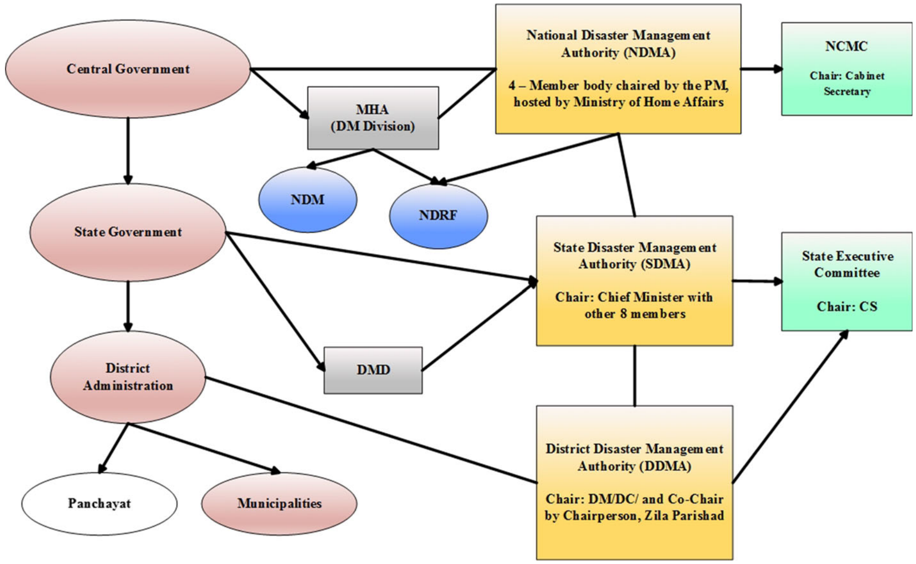

Fig. 4 Institutional framework for disaster management in India (*Source*: *www.ndma.gov.in)

agement (DRM) program in 169 most vulnerable Districts of 17 states in India. Figure 4 illustrates the Institutional framework for disaster management in India.

However, the framework discussed in the whitepaper does not incorporate the feedback of the affected people, the disaster management team and common masses. It is more of a technical blueprint and can be made more effective only if deployed with proper feedback of various stakeholders as visualizing the actual disaster scenario by technical people alone may not be sufficient. Hence, this work is very important to make any technical solution effective at ground level.

4 Research phases and hypotheses development

This research work comprises of the following phases:

- Phase I
  - Identify the information required for deploying relief operations in the disaster area.
  - Identify key challenges faced by the organizations and individuals involved in relief operations.
- Phase II
  - Analyze how and where IoT technology can be applied for addressing the required challenges.
  - Propose a technical IoT based solution for optimizing the relief operations post natural disaster.

- Phase III
    - Validate the proposed solution using the Task-Technology Fit approach that involves a survey with the audience involved in relief operations so as to confirm whether the proposed solution can help in optimizing the relief operations or not. The questions are evaluated using 5-point Likert scale.

4.1 Phase I

Annexure V of the Standard Operating Procedure for Responding to Natural Disaster (Government of India 2010) mentions the information required to be sent to MHA, Government of India within 24 hours of occurrence of the natural calamity. Based on this report and interviews of the NDRF personnel, information required for deploying relief operations in the disaster area can be summarized as:

1. Date and time of the disaster
2. Location information of the affected area
3. Topographical knowledge of the affected sites
4. Number of victims (dead, injured, and missing)
5. Effect on the animal population at the disaster site
6. Effect of the calamity on the natural environment of the affected area
7. Damage to the property
8. Forecast of possible future developments including new risk

Knowledge about the location of the distress scene alone may not be sufficient for inferring the route of relief operations by the land party. Information about the location in conjunction with the topographical information of the disaster site is more helpful in determining the best route to the site. It shall also contribute to the prediction of the magnitude of the disaster. Wang et al. (2016) advocated the importance of the conjunction of proactive response method and logistic expertise for effective relief efforts. Knowledge about the number of victims is of prime concern for planning the amount of relief resources required for planning the rescue operations. Duhamel et al. (2016) proposed the heuristics of operations research and management science to optimize the resilience in the relief operations considering the impact of the distribution of the relief resources on the population. The requirement is not, merely, gathering data from the source but also making it available to the incident commander so that an effective relief operation can be planned. In a country like India, critical information is often delayed in reaching the organisations involved in disaster management operations. This can be attributed to either lack of appropriate technology infrastructure or the complex hierarchy of the organizational structure. Consequently, it may lead to insufficient or less accurate information that is made available to the incident commander. It is, thus, the need of the hour to develop a proper technology infrastructure that can be employed for obtaining accurate and reliable information in real-time.

4.2 Phase II

The proposed IoT based solution for efficient disaster management has the following three key functionality:

1. Information Gathering
2. Information Transmission
3. Information Processing

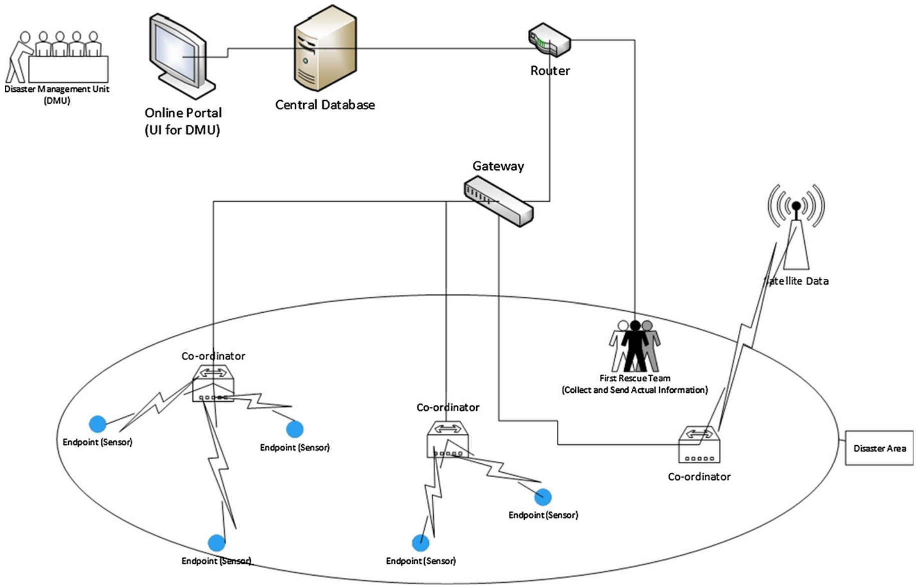

Fig. 5 Overview of the proposed architecture

Figure 5 depicts the high level overview of the proposed IoT based solution for disaster management.

4.2.1 Information gathering

This involves collecting information about the disaster hit area so as to facilitate efficient relief operations. As per the discussion in Phase I, a variety of information is required by the Disaster Management Unit (DMU) to plan for the early rescue operations. For example: in case of flood hit area, getting the knowledge about the current chemical composition of the water in that region can help in deducing the type of disease that can spread as a consequence of contaminated water. The proposed model incorporates various techniques for collecting data at the disaster site that can be used for analyzing real-time conditions of the disaster site.

Emergency logistic planning is an important activity during the rescue operations (Özdamar et al. 2004; Holguín-Veras et al. 2007). Anaya-Arenas et al. (2014) reviewed the significance of the relief distribution networks in disaster management. Logistic planning involves deciding the source of the supply, the amount of supplies (Yang et al. 2016), planning the number and the locations of the distribution centres to be set up, and the number of personnel that needs to be deployed. Burkart et al. (2017) proposed a location-routing model to identify the critical elements for deciding the optimal locations of the relief resource distribution centres in case of natural disasters. These decisions cannot be made only with the knowledge of the location of the disaster scene. The location and topographical information of the disaster site in conjunction can help in determining the best route to the site. The physical conditions of the disaster region can be obtained from the satellites that have been monitoring the region. This data can help in obtaining first hand damage information so as to take decisions about the following: number and nature of rescue teams, kind of equipment, route of operation, mode of transport, feasibility of setting up the relief camps in the disaster region, as well as the location where the relief camps are required to be setup.

Apart from the topological data, knowledge about the atmospheric conditions is also required for determining the resources needed for relief operations, such as air filter types, medicines, mosquito repellents etc. For example, in case of flood hit area, getting the knowledge about the current chemical composition of the water in that region can help in deducing the type of disease that can spread as a consequence of contaminated water. Environmental data can be collected from many sources like sensors, satellites etc. Sensors are low power and resource constrained devices used for collecting specific data from the surroundings. In order to minimize the energy consumption, these sensors are grouped into clusters. Each cluster has a cluster-head which is responsible for transmitting the data gathered by the sensors of that cluster to either the bases station or another cluster-head in case of multi-hop routing (Kumari 2013). These sensors can be used to monitor the quality of air (particle matter, air temperature, humidity, and atmospheric pressure), water as well as chemical composition of the atmosphere (percentage of CO, CO_2, NO_2, O_2, O_3, SO_2 etc.).

The first responders are a crucial part of any relief operations and often provide significant contribution using existing technology such as web portals, message boards, social networking portals, blogs etc. In the past, the capabilities of the Internet technology have been leveraged to gather important information about the disaster. The information was posted on the blogs, which is a type of personal diary in the cyberspace. The blogs had images, videos and first-hand observations about the disaster impact. Information about the missing persons, locations of the shelter and trace of family members have been shared using message boards. Tools such as ShelterFinder and PeopleFinder have been found useful for obtaining information about people requiring immediate shelter and family tracing. These activities are performed at the local level and are the instant response to the effects of the calamity.

Socio-technological networks are unofficial and informal owing to the development of large number of message boards, web portals and blogs. The adoption and expansion of online information sharing strengthens the cyber-community, thereby, connecting people from different geographies. These resources attempt to convey accurate information in a timely manner and in some cases, real-time communications can happen. This spatial information is implicit at this level rather than explicit as in Internet GIS applications (Shrivastava et al. 2011). Spatial information is obtained through questionnaires for identifying the last location of the victims, address information, or shelter locations. Such information also contributes to the prediction of the magnitude of the disaster.

4.2.2 Information communication

One of the key problems faced in disaster management is that the communication gets hampered at the disaster region. Sensor and satellite data collected at the site must be communicated to the DMU so that necessary actions can be taken as quickly as possible. For transmitting the data to the DMU, a gateway connected to the Internet shall be employed. Data collected from the sensors shall be transmitted to the locally deployed coordinator monitoring those sensors (Kumar et al. 2012). Satellite data and the information provided by the local residents shall be communicated directly to the gateway. The gateway shall control the locally deployed coordinators, aggregate the received data and transmit the data over the Internet to the central database maintained by the DMU. This data can be either used to augment the GIS maps maintained at the GIS server or can be viewed on the online portal maintained by the DMU to gather first hand information about the disaster site. It may happen that the Internet services may be disrupted due to the disaster. If such case arises, the DMU shall take preliminary decisions on the basis of the last received data. Meanwhile, the gateway shall keep aggregating the data and store it till the connectivity is restored. It can then transmit the data over the communication channel to the DMU. Even if the connectivity cannot be restored, the personnel visiting the disaster site shall be equipped with a solution (i.e. software/hardware) that can pull the data from gateway. This data shall be transmitted to the DMU by the personnel itself. This shall ensure that information about the disaster site must reach the DMU with minimal interruption.

4.2.3 Information processing

Once the above mentioned information has been communicated to the DMU, it can take necessary actions for regulating the relief operations. The preliminary data shall catalyze the decisions for dispatching short term immediate relief. After the first team is operational in the disaster area, it will send the actual information to the DMU. This actual information will include:

Update on environmental conditions

- Identification of the magnitude of the disaster, e.g. actual numbers on casualties
- Requirements for actual amount of food, medicines, drinking water etc.

This actual information shall help in long term relief planning. Thus, data processing shall be performed in two stages:

1. *When the sensor and satellite data about the disaster site is received at the DMU* This shall help in deducing first hand damage information as well as the environmental conditions at the target site.
2. *When the actual information is sent by the first relief team* This data shall be utilized for analysing the actual requirements for the amount of food, medicines, drinking water etc. Long term relief planning shall be based upon this information.

Figure 6 outlines the flow of information and the sequence of activities during the relief operation.

4.3 Phase III

This phase involves the empirical study of the research problem using Task-Technology Fit as a guiding theoretical lense. The following sub-sections discuss the adopted approach for the evaluation of the proposed IoT based solution for disaster management.

4.3.1 Task-technology fit approach

This research adopts the concepts of TTF with slight modifications. We refer to the ‘task’ as ‘task requirements’ and ‘technology characteristics’ as ‘IoT technology’. Owing to the infancy of the IoT technology in the area of disaster management, the ‘performance impacts’ is referred to as ‘strategic value’ indicating the the overall benefits derived by using the IoT technology to cater the information requirement for disaster management. Fig. 7 depicts the adopted model of Requirements-Technology Fit for analyzing the significance of the IoT technology in enhancing relief operations post natural disasters. Hereafter, the term ‘Task-Technology Fit’ is referred to as ‘Requirements-Technology Fit’ (RTF).

4.3.2 Task requirements

In the context of RTF, tasks can be defined as the activities performed by the individuals for satisfying their information requirements (Goodhue and Thompson 1995). This definition

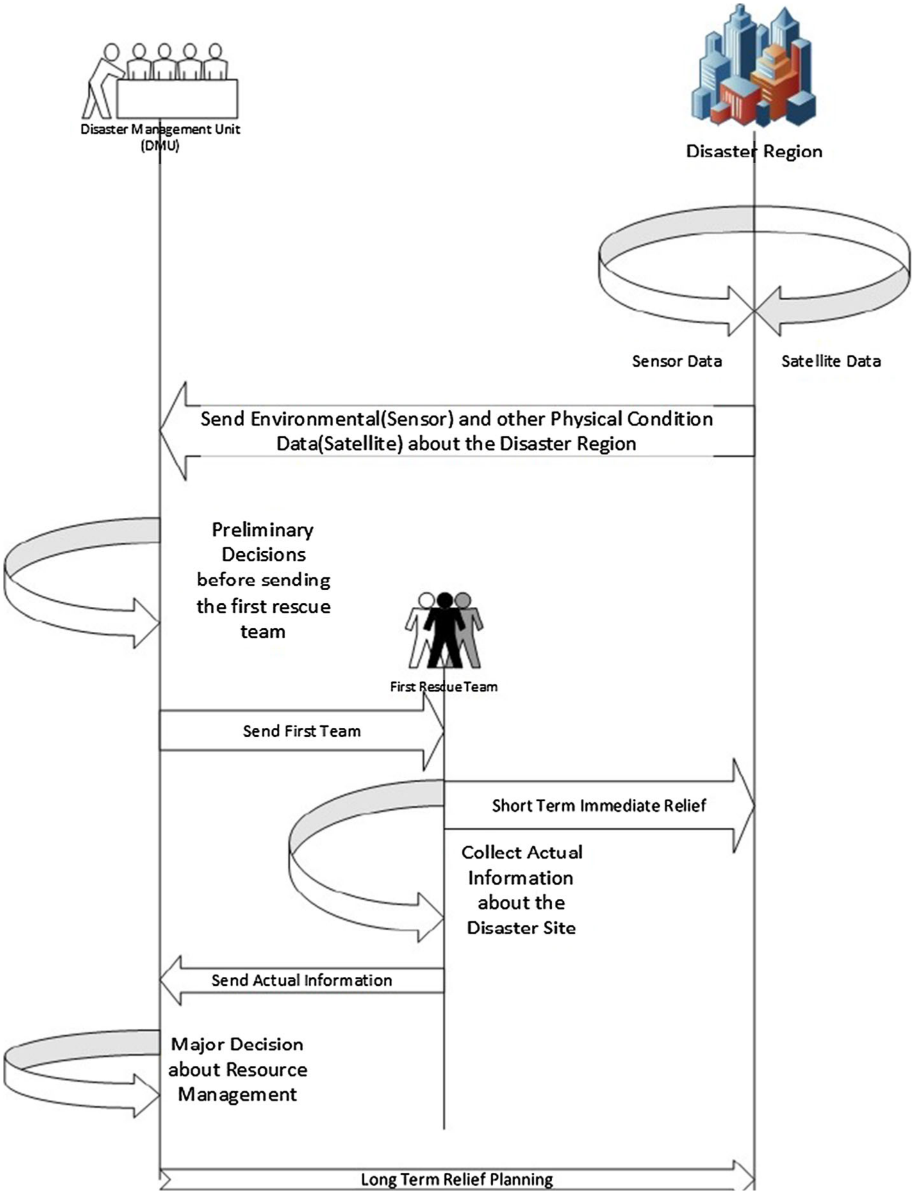

Fig. 6 Information flow and activity sequence during the relief operation

supported our approach for modeling the tasks as the requirements of the personnel for planning the relief operations. Information can be of multiple types such as information about the environment at the disaster site, number of casualties etc. It can be easily inferred that such information is required for assessing the impact of the disaster in order to plan the rescue operations in an efficient manner. Another aspect that must be taken care of is the reliability and consistency of the received information.

In the existing literature, the task construct has been modeled into non-routineness and interdependence (Goodhue and Thompson 1995); quantitative analysis, literature searches,

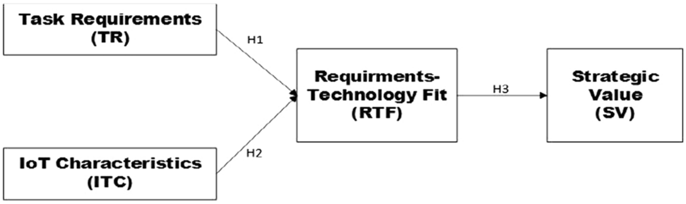

Fig. 7 Requirement-technology fit model (*Source*: Adapted from Goodhue and Thompson 1995; Yang et al. 2013)

text and document organization, and data file access (Goodhue et al. 1997); a set of managerial questionnaire (Goodhue et al. 2000); communication centrality (Belanger et al. 2001); tasks varying in structure (Shirani et al. 1999); use of Internet for resolving uncertainty in personal travel (D'Ambra and Wilson 2004); planning, knowledge building, diagnosis, and modification (Dishaw and Strong 2003); and miscellaneous information tasks (D'Ambra and Rice 2001). However, works that have been carried out in the context of emergency management are more relevant and significant for our research. Different studies have modeled the construct of tasks in the domain of emergency management such as resource management (Holguín-Veras et al. 2007), information management (Celik and Corbacioglu 2010), automation (Carver and Turoff 2007), training (Holguín-Veras et al. 2007) and authentication (Haddow et al. 2008).

Unlike the previous modeling of tasks, this exploratory study considers the construct of task characteristics as an amalgamation of different requirements for an effective and efficient planning of rescue operations. Requirements such as information for assessing the disaster impact, the ability to easily monitor the obtained information and the reliability of the received data have been used to measure the task requirements construct. In the context of this task requirements construct, we propose the following hypothesis:

H1 Task requirements have a positive impact on RTF.

4.3.3 Technology: proposed IoT solution

Technology, in its essence, refers to the tool, hardware or software, utilized by the users to efficiently carry out their tasks (Goodhue and Thompson 1995). In the context of IoT based disaster management, technology implies the IoT based solution that has been proposed to cater the need of various information required for planning the relief operation post any natural disaster (Xu et al. 2014). The RTF model emphasizes the significance of fitting the characteristics and functionality of the technology with the requirements of the individuals involved in disaster management activities (Yang et al. 2013). Substantial literature exists that indicates improved benefits owing to a better fit (Zigurs and Buckland 1998). We considered different functionality of the proposed IoT based solution to devise the scale items for measuring the technology characteristics. Refer "Appendix" for the complete set of items developed to measure the construct of technology. In light of the available evidences from existing literature, we propose the following hypothesis:

H2 IoT technology has a positive effect on RTF.

4.3.4 Modeling TTF for IoT supported disaster management

The existing TTF construct is determined by the eight underlying factors for understanding the adoption of the technology. These factors are authorization, quality, ease of use/training, locatability, reliability, production timeliness, compatibility, and relationship with others (Goodhue and Thompson 1995). However, in the context of disaster management, these factors may convey different realization as compared to their native context. Consequently, four constructs are identified to be incorporated in the adopted research model. These constructs are: situational awareness, consistency, reliability and monitoring.

Situational awareness refers to the ability of assessing the situation based upon the various different information obtained about the disaster (Endsley 1999). This is an extremely critical factor for successful adoption of the proposed IoT based solution for disaster management because of its relevance to the assessment of the disaster impact (Carver and Turoff 2007). *Consistency* implies that information about an entity received from multiple sources must not be anomalous and significantly different. This construct has been referred to as Compatibility by Goodhue and Thompson (1995). The proposed solution must have the ability to provide consistent information derived from multiple source to ensure complete visibility of the impact of the calamity. *Reliability* ensures that the proposed IoT based solution should be able to provide information even in adverse condition. This factor ensures that information can be obtained even in worst conditions and that the system must be ready to use whenever required (Goodhue and Thompson 1995). Finally, *Monitoring* refers to the ability of the proposed system to present the information to the end user in an easy and efficient manner, thereby, improving the analysis of the received information (Robillard and Sambrook 2008; Jiang et al. 2004; Li and Visich 2006; Fang et al. 2014).

4.3.5 Performance impact: strategic value

In the context of disaster management, performance impact denotes the overall strategic value inferred by utilizing the technology to meet the task requirements. High levels of strategic value indicates higher RTF and satisfaction with technology (Goodhue and Thompson 1995). Good RTF increases the overall value derived from the system (D'Ambra et al. 2012). The personnel involved in disaster management need to have multiple information about the impact of the disaster as early as possible. Significant decisions regarding the size of rescue teams, the route of operation and the amount of relief resources required are essential in planning the rescue operations post any disaster. In the current scenario, this information is often delayed in reaching the concerned authority, thereby, increasing the response time of the rescue operations (Anparasan and Lejeune 2017). The proposed IoT based solution delivers the required set of information in real-time to the rescue authorities so that efficient planning of the relief operations can be done as early as possible. The impact of these benefits provided by the proposed IoT based solution on the overall strategic value needs to be determined. In this context, we propose the following hypothesis:

H3 RTF for disaster management has a positive impact on the overall strategic value.

5 Method

This section explains the development of the appropriate measurement scales for empirical evaluation of the IoT based solution in light of the proposed hypothese. It also provides a detailed insight into the demographic profiles of the target audience employed for the survey.

5.1 Instrument development

The adopted research model incorporates nine constructs, out of which three constructs identify the task requirements, one construct refers to the characteristics of the proposed IoT based solution, four different constructs measure the Requirements-Technology Fit and the remaining one construct denotes the strategic value. Due to the lack of measurement items of the identified constructs, the work of Gilbert and Churchill (1979) is followed to formulate new indicators of these constructs. Based on the review of existing literature about disaster management the initial indicators in the form of questionnaire are proposed. These items are reviewed by the experts associated with disaster management and faculties having comprehensive knowledge about the IoT technology. The survey questionnaire is developed both in English and Hindi language, to ensure the consistency of the meanings conveyed to the participants having no or little knowledge of either language. These scales are refined using Exploratory Factor Analysis (EFA) and then Confirmatory Factor Analysis (CFA). This resulted in the development of new indicators for assessing the adopted research model.

The task requirements construct consists of three reflective latent indicators, namely: disaster impact, tracing and tracking and information reliability. These constructs are measured using the newly proposed indicators. IoT characteristics is a formative construct and its measurement scales include the functionality and other attributes of the proposed IoT based solution. The indicators of the requirements-technology fit reflect the fit between task requirements and the functionality of IoT based solution for disaster management. This construct is again of second order and is measured by the four underlying reflective constructs: situation awareness, consistency, reliability and monitoring. The overall benefit derived with this collaboration of task requirements and IoT characteristics is measured by the items of the strategic value construct. The items are formulated as a set of questionnaire and are presented in “Appendix”. Each of the item is measured using a five-point Likert scale, where the answer ranges from ‘Strongly Disagree’ “1” to ‘Strongly Agree’ “5”.

5.2 Participants

The research approach adopted for this work is based upon the principle of induction. The approach is ‘bottom-up’ and initiates with gathering specific observations leading to the identification of patterns. These patterns are further articulated into hypothesis on the basis of which, final conclusions are developed. Owing to the insufficient control over the factors affecting the field study such as the background of the target audience and the level of their technical exposure and knowledge, the adopted approach is inductive in nature. The target audience for the field study consisted of retired army personnel having first hand experience of rescue operations post natural disasters such as earthquake, flood etc. These personnel have national (India) as well as international (Congo, Bhutan, Nepal) experience of the scenarios that prevail post such disasters. Experts associated with the disaster relief unit constituted the second category of the target audience. Apart from these, faculties and students of a technical institution having better technical awareness and knowledge were also included in the target audience. This ensured a better and comprehensive evaluation of all the aspects of the field study. Participants were chosen from various age groups, gender and various levels of educations.

The participants were briefed about the characteristics of the IoT technology and its applicability in the disaster management scenarios. Before handing over the questionnaires, short sessions were conducted to explain the functionality of the IoT based technical solution proposed in this paper. This helped the target audience in gaining the knowledge required to

Table 1 Demographic profile of participants

Demographic parameter	Number of respondents (N = 298)	Percentage (%)
Gender		
Male	202	67.79
Female	96	32.21
Total	298	100.00
Age		
≤ 25	185	62.08
26–34	66	22.15
35 and above	47	15.77
Total	298	100.00
Education		
High school	16	5.37
Intermediate	20	6.71
Graduate	193	64.77
Postgraduate	42	14.09
Doctorate	47	9.06
Total	298	100.00
Occupation		
Student	215	72.18
Faculty	45	14.79
Army Personnel	38	13.03
Total	298	100.00

answer the survey questionnaires. The survey was conducted over a period of two months and the audience were briefed about the survey agenda in groups of 30 to 40 people.

Empirically, the target audience includes 316 participants who have submitted their response through offline methods. In those response, 18 responses were found to be invalid and hence, are not considered in the research work. The detailed demographic profile of the target audience is shown in Table 1.

6 Results

The main objective of this work is to understand the impact of the IoT based solution in catering the task requirements of the personnel involved in disaster management. It is, hence, necessary to first develop valid unidimensional RTF constructs, which shall further be utilized for the evaluation of the use of IoT in disaster management.

Factor analysis with varimax rotation is conducted to analyse the initial measurement scale. The efficiency of the factor analysis is assessed using Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity. The KMO value for the overall degree of sampling adequacy is obtained as 0.735 (> 0.50), and the validity of the instrument is ensured by the Bartlett's test that provided the Chi-square value of 1487.396 having degree of freedom (*df*) as 105 and $p = 0.000$. Factors having eigenvalues > 1 were extracted resulting in five different constructs (3.334, 1.982, 1.847, 1.799, and 1.268). Table 2 shows the EFA of the 15 items with a varimax rotation. The test yielded five factors on the basis of the eigenvalue threshold

Table 2 Results of components extraction for requirement-technology fit (RTF) using principal component analysis (PCA) and varimax rotation with Kaiser normalization

Item ID	Factor 1 (situational awareness)	Factor 2 (consistency)	Factor 3 (reliability)	Factor 4 (monitoring)	Factor 5 (miscellaneous)
RTF2	0.832				
RTF5	0.837				
RTF7	0.843				
RTF4		0.876			
RTF6		0.877			
RTF8		0.845			
RTF9			0.841		
RTF12			0.840		
RTF13			0.812		
RTF10				0.877	
RTF14				0.857	
RTF15				0.869	
RTF1					0.635
RTF3					0.626
RTF11					0.690

of 1. The items significantly load upon five different factors: situation assessment (RTF2, RTF5, RTF7), consistency (RTF4, RTF6, RTF8), reliability (RTF3, RTF9, RTF12, RTF13), monitoring (RTF10, RTF14, RTF15) and Factor 5 miscellaneous (RTF1, RTF3, RTF11) under an overall RTF construct.

Table 3 shows the results from reliability analysis of the extracted factors, having the value of Cronbach's alpha greater than the cut-off value 0.70. The reliability of the identified factors is further enhanced by analysing the corrected item-total correlation. It can be deduced from the table that the individual variance of the Factor 5, i.e. Miscellaneous (8.454%) is relatively less than the other factors (22.543, 13.733, 12.496 and 12.164%). Moreover, the items included in Miscellaneous (Factor 5) seems to evaluate different aspects of the requirements and hence, as such, cannot be clubbed under one construct. This resulted in excluding the indicators measuring Miscellaneous (Factor 5) and having small value for item-total correlations from further analysis. The sum of the squared loadings for the remaining four factors accounted for a cumulative score of 60.935% in inferring the total variance in the data.

Thus, the initial measurement scale is refined by retaining 12 items for the TTF construct, where situation assessment contains three items, consistency contains five items, reliability contains four items and monitoring contains three items.

These 12 items are again tested in the subsequent run of factor analysis. Table 4 depicts the results of the exploratory factor analysis of the reamining 12 items conducted with a varimax rotation. The analysis yielded four different factors depending upon the eigenvalue cutoff of 1. The refined model explains 74.673% of the cumulative variance. The 12 items dovetailed into four factors: situation assessment, consistency, reliability and monitoring. The results of both KMO (0.740) and Bartlett's test of sphericity ($p = 0.000$) are significant. The smallest value obtained for Cronbach's alpha is 0.792 for the reliability construct, which

Table 3 Exploratory factor analysis of RTF construct

Factor name	Items	Loadings	Corrected (item-total correlation)	Eigen value	Individual explained variance	Cronbach's alpha (α)
Situational awareness	RTF2	0.833	0.647	1.825	12.164	0.805
	RTF5	0.838	0.650			
	RTF7	0.846	0.659			
Consistency	RTF4	0.879	0.722	3.381	22.543	0.855
	RTF6	0.880	0.748			
	RTF8	0.852	0.711			
Reliability	RTF9	0.855	0.660	1.874	12.496	0.792
	RTF12	0.847	0.663			
	RTF13	0.812	0.588			
Monitoring	RTF10	0.880	0.738	2.060	13.733	0.851
	RTF14	0.858	0.698			
	RTF15	0.869	0.725			
Miscellaneous	RTF1	0.635	0.165	1.268	8.454	0.338
	RTF3	0.626	0.202			
	RTF11	0.690	0.212			

Table 4 Exploratory factor analysis of RTF construct with scale refinement: final reliability testing

Factor name	Items	Loadings	Corrected (item-total correlation)	Eigen value	Individual explained variance	Cronbach's alpha (α)
Situational awareness	RTF2	0.833	0.647	1.799	14.988	0.805
	RTF5	0.838	0.650			
	RTF7	0.846	0.659			
Consistency	RTF4	0.879	0.722	3.334	27.780	0.855
	RTF6	0.880	0.748			
	RTF8	0.852	0.711			
Reliability	RTF9	0.855	0.66	1.847	15.388	0.792
	RTF12	0.847	0.663			
	RTF13	0.812	0.588			
Monitoring	RTF10	0.880	0.738	1.982	16.517	0.851
	RTF14	0.858	0.698			
	RTF15	0.869	0.725			

satisfies the minimum criteria of 0.70. The smallest corrected-item-total correlation is 0.588, which exceeds the recommended cutoff value of 0.40 as prescribed by Straub et al. (2004). The inter-correlation matrix for the RTF constructs is shown in Table 5. It can be observed that the correlation of the items under one construct is higher than the others. This ensured the reliability of the RTF construct.

Table 5 Final inter-correlation matrix for RTF constructs

	RTF2	RTF4	RTF5	RTF6	RTF7	RTF8	RTF9	RTF10	RTF12	RTF13	RTF14	RTF15
RTF2	1											
RTF4	0.135	1										
RTF5	0.507	0.135	1									
RTF6	0.137	0.684	0.150	1								
RTF7	0.582	0.089	0.586	0.117	1							
RTF8	0.115	0.635	0.244	0.669	0.180	1						
RTF9	0.071	0.091	0.073	0.135	0.094	0.079	1					
RTF10	0.159	0.103	0.144	0.155	0.157	0.178	0.053	1				
RTF12	0.141	0.046	0.169	0.118	0.143	0.094	0.631	0.143	1			
RTF13	0.046	0.110	0.008	0.126	0.017	0.063	0.527	0.037	0.535	1		
RTF14	0.144	0.144	0.132	0.141	0.110	0.191	0.030	0.649	0.117	0.019	1	
RTF15	0.132	0.127	0.112	0.197	0.166	0.190	0.096	0.685	0.130	0.059	0.633	1

Table 6 Components extraction for task requirements using PCA and varimax rotation with Kaiser normalization

Item ID	Factor 1 (disaster impact)	Factor 2 (tracing and tracking)	Factor 3 (information reliability)
TR3	0.843		
TR4	0.886		
TR5	0.790		
TR6		0.771	
TR7		0.859	
TR10		0.805	
TR1			0.822
TR2			0.793
TR8			0.794
TR9			0.853

A similar analysis procedure is adopted for the items of the task-requirements construct. The results of the factor analysis with varimax-rotation for the task-requirements construct is shown in Table 6. The KMO value for the overall degree of sampling adequacy is obtained as 0.710 (> 0.50), and the validity of the instrument is ensured by the Bartlett's test that provided the Chi-square value of 1216.837 having degree of freedom (df) as 45 and $p = 0.000$. The measured items loaded upon three distinct factors having eigenvalue score greater than the accepted threshold of 1. These factors are: disaster impact, tracing and tracking, and information reliability having eigen values of 3.433, 2.050, and 1.555 respectively. The sum of the squared loadings for these factors accounted for a cumulative value of 70.369% of the total explained variance of the observations.

These factors are further tested for reliability. The results obtained from the reliability analysis of these reflective factors is presented in Table 7. The Cronbach's alpha value of each of the three factors exceeded the cutoff of 0.70. The minimum corrected-item-total correlation is 0.57, which exceeds the cutoff value of 0.40. The next step is to conduct the confirmatory factor analysis (CFA) of the overall research model.

6.1 Evaluation of the overall measurement model

We conducted confirmatory factor analysis (CFA) to ensure the parameters of the overall model in terms of reliability, convergent validity, and discriminant validity. Table 8 shows the results of the CFA. The item loadings of all the reflective constructs is greater than 0.7 and significant at $p < 0.01$. The average variance extracted (AVE) and composite reliabilities (CR) are greater than the threshold values of 0.5 and 0.7 respectively. This implies that the own loadings are higher than cross loadings. The convergent validity is, hence, ensured as the reflective items load much higher on their latent constructs than on other constructs.

For the formative constructs (i.e., technology characteristics), the factor weights are analysed rather than factor loadings, which denoted the significance of each item to the latent construct. Table 9 clearly depicts significant contribution of the formative items to the technology construct since they are significant at $p < 0.05$.

Discriminant validity is ensured by analyzing the square root of the AVE, which should be greater than the the value of inter-correlations of the construct with the other constructs. Table 10 shows the results of discriminant validity test. Hence, the measurement model is

Table 7 Results of exploratory factor analysis of 10 task requirements construct: reliability testing

Factor name	Items	Loadings	Corrected (item-total correlation)	Eigen value	Individual explained variance	Cronbach's alpha (α)
Information reliability	TR1	0.822	0.688	3.433	34.326	0.842
	TR2	0.793	0.656			
	TR8	0.794	0.632			
	TR9	0.853	0.734			
Disaster impact	TR3	0.843	0.625	2.050	20.497	0.811
	TR4	0.886	0.714			
	TR5	0.790	0.644			
Tracing and tracking	TR6	0.771	0.570	1.555	15.546	0.765
	TR7	0.859	0.648			
	TR10	0.805	0.582			

Table 8 Results of confirmatory factor analysis (CFA)

Latent constructs	Reflective factors	Items	Loadings	CR	AVE
RTF	Situational awareness	RTF2	0.843	0.805	0.579
		RTF5	0.851		
		RTF7	0.851		
	Consistency	RTF4	0.868	0.855	0.664
		RTF6	0.894		
		RTF8	0.879		
	Reliability	RTF9	0.855	0.798	0.570
		RTF12	0.884		
		RTF13	0.782		
	Monitoring	RTF10	0.888	0.852	0.657
		RTF14	0.861		
		RTF15	0.884		
Task	Disaster impact	TR3	0.795	0.814	0.595
		TR4	0.870		
		TR5	0.882		
	Tracing and tracking	TR6	0.803	0.771	0.531
		TR7	0.843		
		TR10	0.832		
	Information reliability	TR1	0.833	0.844	0.576
		TR2	0.827		
		TR8	0.772		
		TR9	0.862		
Strategic value		SV1	0.826	0.923	0.708
		SV2	0.906		
		SV3	0.909		
		SV4	0.835		
		SV5	0.888		

Table 9 Results of confirmatory factor analysis (CFA) for the formative latent variable

Latent variables	Formative items	Weights	T	VIF
Technology characteristics (TC)	TC1	0.202	1.386	1.189
	TC2	0.090	0.631	1.102
	TC3	0.042	0.301	1.149
	TC4	0.870	10.743	1.062
	TC5	0.027	0.165	1.085
	TC6	0.242	1.691	1.122

considered satisfactory having the support of adequate reliability, convergent validity, and discriminant validity.

We also estimated the factors of the RTF construct as a second-order model. Here, RTF is considered to be represented by situation awareness (b = 0.602), consistency (b = 0.666),

Table 10 Results of discriminant validity test

Latent construct 1	Latent construct 2	Factor correlation	Correlation squared	AVE1	AVE2
Disaster impact	Tracing and tracking	0.325	0.106	0.595	0.531
Disaster impact	Information reliability	0.244	0.060	0.595	0.576
Disaster impact	Technology characteristics	0.397	0.158	0.595	0.169
Tracing and tracking	Information reliability	0.295	0.087	0.531	0.576
Tracing and tracking	Technology characteristics	0.362	0.131	0.531	0.169
Information reliability	Technology characteristics	0.331	0.110	0.576	0.169
Situational awareness	Consistency	0.230	0.052	0.579	0.664
Situational awareness	Reliability	0.177	0.031	0.579	0.570
Situational awareness	Monitoring	0.228	0.052	0.579	0.657
Situational awareness	Strategic value	0.213	0.045	0.579	0.708
Consistency	Reliability	0.152	0.023	0.664	0.570
Consistency	Monitoring	0.238	0.057	0.664	0.657
Consistency	Strategic value	0.242	0.059	0.664	0.708
Monitoring	Strategic value	0.324	0.105	0.657	0.708
Reliability	Monitoring	0.147	0.022	0.570	0.657
Reliability	Strategic value	0.235	0.055	0.570	0.708
Disaster impact	Situational awareness	0.074	0.005	0.595	0.579
Disaster impact	Consistency	0.220	0.048	0.595	0.664
Disaster impact	Reliability	0.071	0.005	0.595	0.570

Table 10 continued

Latent construct 1	Latent construct 2	Factor correlation	Correlation squared	AVE1	AVE2
Disaster impact	Monitoring	0.304	0.092	0.595	0.657
Disaster impact	Strategic value	0.300	0.090	0.595	0.708
Tracing and tracking	Situation awareness	0.302	0.091	0.531	0.579
Tracing and tracking	Consistency	0.250	0.063	0.531	0.664
Tracing and tracking	Reliability	0.254	0.065	0.531	0.570
Tracing and tracking	Monitoring	0.229	0.052	0.531	0.657
Tracing and tracking	Strategic value	0.351	0.123	0.531	0.708
Information reliability	Situational awareness	0.073	0.005	0.576	0.579
Information reliability	Consistency	0.163	0.027	0.576	0.664
Information reliability	Reliability	0.333	0.111	0.576	0.570
Information Reliability	Monitoring	0.059	0.003	0.576	0.657
Information Reliability	Strategic value	0.268	0.072	0.576	0.708
Strategic value	Technology characteristics	0.585	0.342	0.708	0.169
Monitoring	Technology characteristics	0.415	0.172	0.657	0.169
Reliability	Technology characteristics	0.504	0.254	0.570	0.169
Consistency	Technology characteristics	0.296	0.088	0.664	0.169
Situation awareness	Technology characteristics	0.263	0.069	0.579	0.169

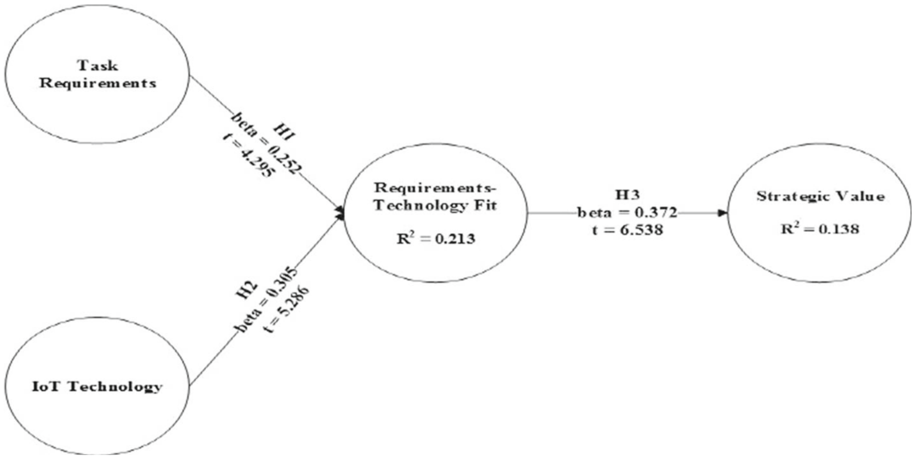

Fig. 8 Validated requirement technology fit (RTF) model

reliability (b = 0.492) and monitoring (b = 0.661) constructs, having 60, 67, 49 and 66% of overall TTF variance respectively. This implies that consistency has the greatest reflection of the overall TTF construct, followed by monitoring, situation awareness and reliability.

6.2 Structural model

The results of the structural relation are analyzed using the standardized solution provided by PLS. Figure 8 depicts the the path coefficients and r^2 values. The obtained values report sufficient evidences in support of the proposed hypothesis. The model explicates a substantial portion (52%) of the variance of the strategic value construct. The variance for RTF is 21.8%. The model specifies all the six causal paths and clearly indicates that all paths are statistically significant ($p < 0.005$). These causal paths denote the significant positive effect of task requirements (i.e. hypothesis H1) and IoT technology (i.e. hypothesis H2) on the RTF for the proposed IoT based solution in the disaster management scenario. The results also convey the significance of the RTF on the overall strategic value derived from this collaboration (i.e. hypothesis H3). Thus, the RTF model is employed to analyze its predictive power in terms of the adoption of IoT technology by the personnel involved in disaster management. The paths depicted in the model are significant in explaining the direct and indirect effects of the RTF of IoT technology. The overall model accounts for 13.8% of the variance for the strategic value in performing disaster management using IoT based technology. This indicates the efficiency of the adopted research model in evaluating the benefits delivered to the society by using the required technology to cater the task requirements. The results, hence, signify that the requirements-technology strategic value chain is an appropriate theoretical framework for analyzing the adoption of IoT based solution by the disaster management personnel.

Based on the available literature about the disaster management and TTF, the direct effects of the precursors on the RTF (task requirements and IoT characteristics) have been examined. As hypothesized, task-requirements (0.252) and IoT technology (0.305) have a significant impact on disaster management RTF. The precursors of task requirements and IoT technology explained 21.3% of the variance in RTF. Table 11 highlights the assessment of the individual path coefficients corresponding to our propositions.

Table 11 Proposed Hypotheses

Index	Proposed hypothesis	Path coefficients	t value	Supported/not-supported
H1	Task requirements have a positive impact on RTF	0.252	4.295	Supported
H2	IoT technology has a positive effect on RTF	0.305	5.286	Supported
H3	RTF for disaster management has a positive impact on the overall strategic value	0.372	6.538	Supported

It can be clearly observed that all three proposed hypotheses are well supported. These results lay the foundation for the development of the additional constructs for enhancing the accuracy of the Task-Technology Fit model in evaluating the significance of the adoption of Iot based technologies in the context of disaster management.

7 Discussion

In this paper, an IoT based solution is presented to facilitate the disaster management activities. The proposed solution incorporates the various aspects of information gathering, information communication, and information processing for catering the task requirements of immediate relief operations. The aim of the proposed solution is to provide accurate information in real-time. Better situation awareness is provided by collaborating the information from multiple sources. This information is presented to the end-user as per their requirements. In the initial stages, this research identified the key requirements for carrying out the immediate relief operations. This information drove the development of the proposed IoT based framework and as such, the functionality of the solution efficiently aligns with the task requirements. Initial assessment of the proposed IoT based solution by the experts having experience of disaster management and technological awareness has been quite motivating.

The proposed model is further validated using the modified TTF approach, RTF, to examine the significance of the model in the disaster management scenarios. Due to the presence of limited relevant literature, this exploratory study required the development of appropriate fit constructs to evaluate the overall benefits derived by using the proposed solution for disaster management.

To evaluate the solution using RTF approach, new and relevant constructs are developed and refined to increase the effectiveness of the TTF model. As such, the task requirements has been classified into three dimensions: disaster impact, tracing and tracking and information reliability. Similar approach is employed to reduce the dimensions of the scales measuring the RTF construct, which is found to be a cause of the following four reflective indicators: situational awareness, consistency, reliability, and monitoring. The results obtained satisfied our propositions about the task and technology having significant impact on the RTF. The results also indicates the significance of a good fit construct for having a better strategic value of the system.

Owing to the availability of limited literature regarding the evaluation of the impact of IoT in disaster management, the findings of this research work have been assessed in light of the similar work performed for different domains. As such, the analysis of the research findings in light of the proposed hypotheses considers similar postulates available in the existing literature but in different context.

H1 Effect of Task Requirements on RTF: It can be deduced from the research findings that a significant relationship exists between the requirements of the tasks and the corresponding RTF. This result is consistent with those in the existing literature (Barki et al. 2007; Dishaw and Strong 1999; Goodhue and Thompson 1995). This can be attributed to the fact that the task requirements are an important driver for determining the fitness or suitability of the technology that needs to be employed for achieving the task objectives. We found that the personnel who are either currently involved or had some past experience of disaster management are well aware about the challenges that are faced during post disaster relief operations and as such tend to give high scores to the RTF scales, thereby reflecting the fitness of the technology required to meet the task requirements. For example, the first team of incident responders have limited knowledge about the effects of the disaster and hence, shall demand a technology that can give a comprehensive information regarding the post disaster effect as early as possible.

H2 Effect of IoT Technology Characteristics on RTF: The characteristics of the IoT technology encompasses the different technical aspects of IoT to address the diverse requirements of the personnel involved in post disaster relief operations (Fang et al. 2014). The construct of the IoT technology characteristics have been found to be a key predictor for the RTF factors. This can be understood by the fact that the ubiquitous nature of the IoT makes it promising technology in shaping the fit of the technology to the scenarios involving remote monitoring and distance communications (Xu et al. 2014). As the target audience for the survey involved the technical students as well as the technology experts, it is safe to deduce that their responses indicate the potential of the IoT technology to cater the information requirements for the post-disaster relief operations.

H3 Effect of RTF on overall Strategic Value: Our third hypothesis is to deduce the impact of the Requirements-Technology Fit on the overall Strategic Value delivered to the society. This is indicated by the arrow from RTF to the Strategic value construct in the full model. Owing to the statistical significance ($p < 0.005$) of the causal path between the aforementioned constructs, it can be concluded that the identified factors for the RTF construct are significant predictors of the overall strategic value. This is consistent with the existing literature which emphasizes upon the importance of good fit construct for deriving better strategic value from the system (D'Ambra et al. 2013; Fosso Wamba et al. 2016; Goodhue and Thompson 1995; Huang and Chuang 2016). This can be understood by the fact that the greater the extent of the requirements satisfied by a technology more will be the derived benefits.

7.1 Theoretical contributions

The empirical research presented in this paper provides valuable insights into the potential of the IoT technology in catering the requirements of the post-disaster relief activities. Very few research studies exist in the literature that tend to investigate the adoption of IoT technology in disaster management (Fosso Wamba et al. 2016; Wang et al. 2009; Yang et al. 2009, 2013). Due to diverse information requirements of the emergency responses, it is the need of the hour to utilize the benefits of the latest technology in catering to the needs of the personnel involved in the post-disaster relief activities. Hence, one of the major theoretical contributions of this work is that it provides a model for evaluating the fitness of IoT technology in the domain of disaster management. To the best of our knowledge, this happens to be the first research that empirically evaluates the fitness constructs for the IoT technology in the context of disaster management.

Owing to the insufficient available literature regarding the fitness of IoT for disaster management, this study proposes new and relevant factors that can be used for examining the benefits that can be derived from employing the IoT solutions for immediate emergency responses post any natural disasters. The study, hence, should be utilized as the motivational work by other researchers for developing additional factors of the TTF construct for IoT technology with the aim of enhancing the accuracy of the model.

This work adopts the higher-order reflective approach for modelling the TTF construct. The various dimension of the fitness construct, viz. situational awareness, consistency, reliability, and monitoring have been considered to be the reflections of the overall TTF construct having significant internal consistency and high positive correlation. This can be attributed to the fact that the identified indicators of RTF construct adhere to a common motif and hence the removal of any indicator would not modify logical implication of the construct. Moreover, the unidimensional nature of these indicators provides the facility to improve the accuracy of the construct without altering the content validity. The adopted approach for reflective modelling is explicitly driven by the literature regarding "the nature and direction of the relationship between constructs and measures" (Edwards and Bagozzi 2000, p. 156). The empirical findings of this research aligned with the existing literature (Wetzels et al. 2009; Yang et al. 2009) confirms the TTF for IoT technology as a high-order reflective construct in the context of disaster management. This is consistent with the prior research specifying the fit construct of TTF model as a high-order reflective construct (D'Ambra et al. 2013).

7.2 Implications for practice

The occurrence of disasters cannot be stopped by humans. The only option mankind can choose is to develop authentic prediction mechanisms to limit the damage and to streamline the disaster management operations by adequate planning, using up-to-date developments in the field of information technology. The minimum the human population could aim for is to mitigate the post-disaster effects as far as possible by appropriate estimation of the scale of damage, the area affected, causalities, and immediate and long term relief requirements. However, one of the major obstacles faced by the organizations involved in managing the post-disaster relief operations is the improper resource allocation (Anparasan and Lejeune 2017). Resources may refer to any kind of equipment, medicines, edible items or even the personnel deployed onsite for carrying out the relief work. As already discussed in Sect. 3, the disaster management scenario in India is still naïve and quite complex as compared to the other developed countries. The uneven resource allocation can directly be attributed to the delay and inconsistency in obtaining the information that can outline the post disaster situation (Carver and Turoff 2007). This research proposes a technical infrastructure (see Fig. 5) that will help the disaster management organizations in gaining a comprehensive visibility of the post disaster scenario. This can be achieved by integrating information obtained from the multiple sources, such as sensors, satellites, GIS. Environmental data obtained from the sensors alone are not enough for planning the disaster management activities. Appropriate knowledge about the geographical conditions of the disaster site is also significant. This information will be utilized in planning the route of the relief effort, which is another vital activity for the disaster management planning. The integration of RFID technology in the proposed IoT based infrastructure (shown in Fig. 5) can facilitate better monitoring of the dispatched resources. This information is crucial and is required for an effective management of rescue operations and efficient coordination with the deployed personnel. Real-time communication of this information to the disaster management unit shall help them in dispatching timely response to the disaster site.

The empirical validation of the proposed IoT based solution using the RTF model discussed in Sect. 6 further provides significant investigation of the capability of the IoT technology for catering the requirements of disaster management activities. This work tailored the existing TTF model and incorporated relevant constructs so as to align its applicability in the context of disaster management. The findings of the statistical investigation shall aid the disaster management organizations to evaluate emerging IoT based solution against the requirements of the tasks in the disaster management scenario. Since, full scale simulation of disaster is not possible and one cannot take chances by trial and error in the selection of technology for disaster management, a balanced and effective model for deciding the most suited technology is required.

The findings of this research suggest that the requirements for carrying out the post-disaster relief effort involves three critical aspects; viz. information regarding disaster impact, the reliability of the obtained information and the capability to trace and track the resources. This classification of the overall requirements for the rescue operations can be used as the guidelines by the relief organizations for investing sufficient efforts in each category. Moreover, the research emphasizes upon the importance of the appropriate RTF constructs for enhancing the overall strategic value delivered to the society. This is strongly supported by several important research studies (Dishaw and Strong 1999; Fosso Wamba et al. 2016; Goodhue and Thompson 1995; Huang and Chuang 2016; Zigurs and Buckland 1998). Accordingly, this research identified four major fitness constructs, i.e. situational awareness, consistency, reliability and monitoring that can assist the organizations in evaluating the suitability of the technology, as per the requirements of the emergency relief operations, before adopting them. The significance of these fitness constructs can also serve as the guidelines to the solution vendors that aim to develop products to aid in the disaster management.

The fitness construct ‘consistency’ is found to have the most significant effect on the overall RTF construct. Subsequently, the reliability construct is also found to be significant determinant of the overall fitness of the technology. This information should be utilized by developers of the IoT based solutions to ensure that the information being provided by their products must be consistent and reliable throughout the service being provided. This is required because any vague or ambiguous information can lead to a haphazard situation which shall eventually hamper the entire rescue operation (Altay and Green 2006; Smith and Dowell 2000; Turoff et al. 2004). Information regarding the disaster site for evaluating the post-disaster effects is often crucial for an efficient planning of the rescue efforts (Carver and Turoff 2007; Perry 2003; Tomaszewski 2011). The findings of this research identify situational awareness to be a significant construct for a technology to be considered fit for disaster management. This clearly suggests that the organization responsible for disaster management must consider the type of information which can be availed for gaining sufficient visibility of the post-disaster conditions by using a particular technology. The more comprehensive the information is, the more suitable is that technology.

Merely obtaining the information about the disaster site and deploying suitable relief resources is not sufficient for the success of any emergency relief operation (Altay and Green 2006; Perry 2003; van Wassenhove 2006). This can be deduced from the fact that the second most important fitness construct, in the context of disaster management, has been identified as monitoring. Consequently, the disaster management organizations must also consider whether the technology that is planned to be utilized for enhancing the efficacy of the rescue operations has the capability to track and monitor the status of the deployed as well as the overall relief resources.

8 Conclusion

Disaster management is not a one step process. Suitable actions at every stage of the disaster management cycle ensures better preparedness, improved and reliable early warnings, reduced vulnerability or the mitigation of the disaster impact during the subsequent recursion of the cycle. The entire disaster management cycle requires the formulation of public policies and strategies that either minimize the causes of disasters or their effects on individuals and infrastructure. The research presented in this paper proposes an innovative IoT based solution to provide real time information about disaster hit area so as to facilitate immediate and effective decisions regarding the rescue efforts. The main objective of this research is to investigate the fitness of the proposed IoT based solution in achieving the tasks required for immediate relief operation after any natural calamity has taken place. For this purpose, the research employs the existing TTF model customized for its applicability in the context of diaster management. During post-disaster relief operations, there is an immediate requirement of certain types of information for assessing the impact of the disaster and planning an efficient relief operation. This requires on-site information systems for providing such information about the environmental conditions, number of casualties, response personnel, and the available rescue resources that can enable the incident responders to take suitable decisions for the rescue operations.

This work contributes significantly to the research about the impact of the IoT technology for disaster management. From acquiring the essential requirements of the tasks in the relief operations to proposing an IoT based solution for catering such requirements and validating the proposed solution in terms of fitness, this paper presents a comprehensive study of the application of IoT in disaster management. Any emergency system is successful if the correct information is collected, shared with the right people and presented in a right format. It is, hence, safe to deduce that the IoT based solution proposed in this paper has the potential to suffice the requirements of a wide range of emergency response applications.The paper also proposes a modified TTF model to evaluate the impact of the proposed IoT based solution on disaster management. Results obtained from our study are strong indicators of the applicability of the IoT technology in diaster management. It is essential to state that the findings of this research shall pave the grounds for the development of relevant IoT based solutions with the aim of addressing the requirements of the personnel (government or non-government) in managing the post disaster rescue operations.

8.1 Limitations and future research

IS models help in shaping the knowledge of the person regarding a phenomenon and at the same time, it also aims to clarify and communicate this knowledge to others. However, once formulated, the model may tend to align the philosophy of the researchers with the facets of the model. It is, hence, extremely crucial to examine the aspects of future research with the aim of expanding the scope of the model across diversified scenarios. The work presented in this paper builds upon the existing TTF model (Goodhue and Thompson 1995) and aims to recalibrate the TTF constructs for the application of IoT technology in disaster management. Although, this work adds to the knowledge base of the TTF measurements, the model may be further enhanced to improve the functionality and reach.

Most of the existing literature employs the conglomeration of technology acceptance model (TAM) and TTF with the auxiliary aim of identifying the vital indicators for technology acceptance by the potential adopters (Usoro et al. 2010; Yen et al. 2010). The methodology discussed in this paper does not incorporate TAM under the assumption that wherever possible, the IoT technology will be adopted by the personnel involved in disaster management. This provides the room for future work of expanding the scope of the approach employed in this research to incorporate the technology adoption aspects and models (see for example, Dwivedi et al. 2017a, b; Rana and Dwivedi 2015; Rana et al. 2016, 2017). This is particularly important as a large number of IS/IT projects fail (Dwivedi et al. 2014; Hughes et al. 2016, 2017) due to lack of adoption and use of technologies and/or applications in question.

Another limitation of the proposed model is that it does not consider the utilization as a precursor for the strategic value. The low R^2 value for strategic value can be directly attributed to this fact since prior studies have confirmed the importance of both task-technology fit and utilization in predicting the performance impacts which in our case refers to the strategic value delivered to the society (D'Ambra et al. 2013; Goodhue and Thompson 1995). This leads to the possibility of improving the research by analysing the impact of TTF in conjunction with the utilization construct on the strategic value.

The selection of constructs and their corresponding measurement scales plays a significant role in the research being carried out in the area of IS. Our research required development of appropriate scales for measuring the constructs in the context of disaster management. Owing to the lack of literature pertaining to the application of TTF model in the disaster management domain, many measurement variables needed to be developed and refined in order to evaluate the proposed hypotheses. It is also vital to state that the list of identified factors of the modified TTF model is not comprehensive in nature and, hence, can be further enhanced by the researchers for improving the validity and accuracy of the TTF model for its application in the disaster management domain. It can, hence, be deduced that there is ample scope for incorporating additional construct in order to refine the existing dimensions of TTF for enhancing the accuracy of the proposed model.

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Appendix: Survey questionnaire

Construct	Item ID	Item
Task requirements (Goodhue and Thompson 1995; Yang et al. 2013; Fang et al. 2014)	TR1	First responders have little information about the impact of disaster on the way to scene
	TR2	It is very important to obtain the accurate knowledge of the disaster as early as possible
	TR3	The topological information about the disaster site is not available beforehand
	TR4	Information about the environmental conditions at the disaster site is not available in the initial stages of the rescue operations
	TR5	Knowledge about the number and location of the victims is important for estimating the resources required for rescue services

Construct	Item ID	Item
	TR6	The rescue items dispatched to the disaster site cannot be tracked or monitored, thereby, making the resource management a difficult task
	TR7	Tracking the activities of the deployed rescue teams is crucial but not always achievable
	TR8	Data about the disaster is often lost due to adverse conditions
	TR9	Information about the disaster is often delayed in reaching the rescue teams
	TR10	Information about the disaster should be easy to analyse and share
IoT technology (Yang et al. 2013; Fang et al. 2014)	TC1	The proposed solution is able to provide knowledge about the geographical and environmental conditions of the disaster site
	TC2	By using the proposed solution, tracing and tracking of the required objects can be achieved
	TC3	The proposed solution can provide information about the disaster site in real time
	TC4	Information available from different components of the deployed solution is collaborated and the final data is presented
	TC5	The proposed solution offers multiple formats for viewing the obtained information
	TC6	Information in the proposed solution is not lost even if the communication between the disaster site and rescue centre is hampered
Requirements-technology fit (Goodhue and Thompson 1995; Carver and Turoff 2007; Yang et al. 2013; Robillard and Sambrook 2008; Jiang et al. 2004;Li and Visich 2006)	RTF1	Assessment of the situation is well supported
	RTF2	It is easy to gather knowledge about the number of casualties
	RTF3	Accurate information is available in real-time
	RTF4	At times, information obtained from different sources is inconsistent
	RTF5	It is easy to obtain information about the environmental conditions of the disaster site
	RTF6	When it is necessary to compare or consolidate data from multiple sources, it has been found that there exists inconsistencies
	RTF7	Geographical information about the disaster site is available before hand
	RTF8	Sometimes it is difficult to compare or consolidate data from different sources because the data is defined differently
	RTF9	The system can be relied upon to be “up” and available when information is needed
	RTF10	Information can be easily viewed as per the requirement
	RTF11	I can view information in the format of my choice
	RTF12	Available information can be easily shared between the organizations
	RTF13	At times, information is unexpectedly lost due to communication failure

Construct	Item ID	Item
	RTF14	Availability of resources is easy to monitor
	RTF15	Personnel deployed for rescue operations can be easily tracked
Strategic value (Yang et al. 2013)	SV1	The proposed solution ensures better awareness of the situation and comprehensive visibility of the disaster effect
	SV2	The proposed solution helps in efficient planning of the rescue operations
	SV3	The proposed solution facilitates better management of the rescue resources
	SV4	The proposed solution enables efficient cooperation between different agencies involved in the disaster management
	SV5	The proposed solution reduc es the response time for the rescue operations

References

Altay, N., & Green, W. G. (2006). OR/MS research in disaster operations management. *European Journal of Operational Research*, *175*(1), 475–493.

Anaya-Arenas, A. M., Renaud, J., & Ruiz, A. (2014). Relief distribution networks: A systematic review. *Annals of Operations Research*, *223*(1), 53–79.

Anparasan, A., & Lejeune, M. (2017). Resource deployment and donation allocation for epidemic outbreaks. *Annals of Operations Research*. doi:10.1007/s10479-016-2392-0.

Belanger, F., Collins, R. W., & Cheney, P. H. (2001). Technology requirements and work group communications for telecommuters. *Information Systems Research*, *12*(2), 155–176.

Broll, G., Rukzio, E., Paolucci, M., Wagner, M., Schmidt, A., & Hussmann, H. (2009). Perci: Pervasive service interaction with the internet of things. *IEEE Internet Computing*, *13*(6), 74–81.

Burkart, C., Nolz, P. C., & Gutjahr, W. J. (2017). Modelling beneficiaries' choice in disaster relief logistics. *Annals of Operations Research*, *256*(1), 41–61.

Carver, M., & Turoff, M. (2007). Human–computer interaction: the human and computer as a team in emergency management information systems. *Communications of the ACM - Emergency Response Information Systems: Emerging Trends and Technologies*, *50*(3), 33–38.

Celik, S., & Corbacioglu, S. (2010). Role of information in collective action in dynamic disaster environments. *Disasters*, *34*(1), 137–154.

D'Ambra, J., & Rice, R. E. (2001). Emerging factors in user evaluation of the world wide web. *Information and Management*, *38*(6), 373–384.

D'Ambra, J., & Wilson, C. S. (2004). Use of the world wide web for international travel: Integrating the construct of uncertainty in information seeking and the task-technology fit model. *Journal of the American Society for Information Science and Technology*, *55*(8), 731–742.

D'Ambra, J., Wilson, C. S., & Akter, S. (2013). Application of the task-technology fit model to structure and evaluate the adoption of E-books by Academics. *Journal of the American Society for Information Science and Technology*, *64*(1), 48–64.

Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. *IEEE Transactions on Industrial Informatics*, *10*(4), 2233–2243.

Darianian, M., &Michael, M. P. (2008). Smart home mobile RFID-based Internet-of-Things systems and services. In*International conference on advanced computer theory and engineering, 2008. ICACTE'08* (pp. 116–120). IEEE.

Digital India Action Group. (2016). Internet of things (iot) for effective disaster management. Whitepaper.

Dishaw, M. T., & Strong, D. M. (1999). Extending the technology acceptance model with task-technology fit constructs. *Information & Management*, *36*(1), 9–21.

Dishaw, M. T., & Strong, D. M. (2003). The effect of task and tool experience on maintenance case tool usage. *Information Resources Management Journal*, *16*(3), 1–16.

Duhamel, C., Santos, A. C., Brasil, D. Ann, Res, Oper, et al. (2016). Connecting a population dynamic model with a multi-period location–allocation problem for post-disaster relief operations. *Annals of Operations Research*, *247*(2), 693–713.

Dwivedi, Y. K., Rana, N. P., Jeyaraj, A., Clement, M., & Williams, M. D. (2017a). Re-examining the unified theory of acceptance and use of technology (UTAUT): Towards a revised theoretical model. *Information Systems Frontiers*. doi:10.1007/s10796-017-9774-y.

Dwivedi, Y. K., Rana, N. P., Janssen, M., Lal, B., Williams, M. D., & Clement, M. (2017b). An empirical validation of a unified model of electronic government adoption (UMEGA). *Government Information Quarterly*. doi:10.1016/j.giq.2017.03.001.

Dwivedi, Y., Wastell, D., Laumer, S., Henriksen, H., Myers, M., Bunker, D., et al. (2014). Research on information systems failures and successes: Status update and future directions. *Information Systems Frontiers*, *17*(1), 143–157.

Edwards, J. R., & Bagozzi, R. P. (2000). On the nature and direction of relationships between constructs. *Psychological Methods*, *5*(2), 155–174.

Endsley, M. R. (1999). Situation awareness and human error: designing to support human performance. In *High consequence systems surety conference*, 1999.

Fleisch, E. (2010). What is the internet of things? An economic perspective. *Economics, Management, and Financial Markets*, *2*, 125–157.

Fosso Wamba, S., Gunasekaran, A., Bhattacharya, M., & Dubey, R. (2016). Determinants of RFID adoption intention by SMEs: An empirical investigation. *Production Planning & Control*, *27*(12), 979–990.

Gershenfeld, N., Krikorian, R., & Cohen, D. (2004). Internet of things. *Scientific American*, *291*, 76–81.

Gilbert, Jr, & Churchill, A. (1979). A paradigm for developing better measures for marketing constructs. *Journal of Marketing Research*, *16*(1), 64–73.

Goodhue, D. L., & Thompson, R. L. (1995). Task-technology fit and individual performance. *MIS Quarterly*, *19*, 213–236.

Goodhue, D. L., Klein, B. D., & March, S. T. (2000). User evaluations of IS as surrogates for objective performance. *Information & Management*, *38*(2), 87–101.

Goodhue, D., Littlefield, R., & Straub, D. W. (1997). The measurement of the impacts of the IIC on the end-users: The survey. *Journal of the Association for Information Science and Technology*, *48*(5), 454–465.

Government of India Ministry of Home affairs. Standard operating procedure for responding to natural disaster, 2010.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, *29*(7), 1645–1660.

Haddow, D. G., Bullock, A. J., & Coppola, P. D. (2008). *Introduction to emergency management*. Burlington: Elsevier.

Holguín-Veras, J., Pérez, N., Ukkusuri, S., Wachtendorf, T., & Brown, B. (2007). Emergency logistics issues affecting the response to Katrina: A synthesis and preliminary suggestions for improvement. *Transportation Research Record: Journal of the Transportation Research Board*, *2022*, 76–82.

Huang, K. Y., & Chuang, Y. R. (2016). A task-technology fit view of job search website impact on performance effects: An empirical analysis from Taiwan. *Cogent Business & Management*, *3*(1), 1–18.

Hughes, D. L., Dwivedi, Y. K., & Rana, N. P. (2017). Mapping IS Failure Factors on PRINCE2® Stages: An Application of Interpretive Ranking Process (IRP). *Production Planning & Control*, *28*(9), 776–790.

Hughes, D. L., Dwivedi, Y. K., Rana, N. P., & Simintiras, A. C. (2016). Information systems project failure-analysis of causal links using interpretive structural modelling. *Production Planning & Control*, *27*(16), 1313–1333.

INFSO, D. (2008). Networked Enterprise & RFID INFSO G. 2 Micro & Nanosystems, in co-operation with the Working Group RFID of the ETP EPOSS, Internet of Things in 2020, Roadmap for the Future [R].*Information Society and Media, Tech. Rep*.

International Telecommunication Union. Itu internet reports 2005: The internet of things. *Workshop Report*, 2005.

Jiang, X., Hong, J. I., Takayama, L. A., & Landay, J. A. (2004). Ubiquitous computing for firefighters: Field studies and prototypes of large displays for incident command. In*Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 679–686). ACM.

Dai, J., Wang, S., & Yang, X. (1994). Computerized support systems for emergency decision making. *Annals of Operations Research*, *51*(7), 313–325.

Kristensen, M., Kyng, M., & Palen, L. (2006). Participatory design in emergency medical service: Designing for future practice. In*Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 161–170). ACM.

Kumar, P., Singh, M. P., & Triar, U. S. (2012). A review of routing protocols in wireless sensor network. *International Journal of Engineering Research &Technology (IJERT)*, *1*(4), 1–14.

Kumari, P., Singh, M., & Kumar, P. (2013). Cluster head selection in mobile wireless sensor networks: A survey. In*International conferences on advances in computing and communication* (pp. 978–981).

Kyng, M., Nielsen, E. T., & Kristensen, M. (2006). Challenges in designing interactive systems for emergency response. In *Proceedings of the 6th conference on designing interactive systems* (pp. 301–310). ACM.

Lee, E. K., Maheshwary, S., Mason, J., & Glisson, W. (2006). Decision support system for mass dispensing of medications for infectious disease outbreaks and bioterrorist attacks. *Annals of Operations Research*, *148*(1), 25–53.

Lei, L., Pinedo, M., Qi, L., Wang, S., & Yang, J. (2015). Personnel scheduling and supplies provisioning in emergency relief operations. *Annals of Operations Research*, *235*(1), 487–515.

Li, S., & Visich, J. K. (2006). Radio frequency identification: Supply chain impact and implementation challenges. *International Journal of Integrated Supply Management*, *2*(4), 407–424.

Llic, A., Staake, T., & Fleisch, E. (2009). Using sensor information to reduce the carbon footprint of perishable goods. *EEE Pervasive Computing*, *8*(1), 22–29.

NDMG. (2010). *A publication of the National Disaster Management Authority*. National Disaster Management Guidelines-Incident Response System: Government of India. ISBN 978-93-80440-03-3.

Niyato, D., Hossain, E., & Camorlinga, S. (2009). Remote patient monitoring service using heterogeneous wireless access networks: Architecture and optimization. *IEEE Journal on Selected Areas in Communications*, *27*(4), 412–423.

Özdamar, L., Ekinci, E., & Küçükyazici, B. (2004). Emergency logistics planning in natural disasters. *Annals of Operations Research*, *129*(1), 217–245.

Oztekin, A., Pajouh, F. M., Delen, D., & Swim, L. K. (2010). An RFID network design methodology for asset tracking in healthcare. *Decision Support Systems*, *49*(1), 100–109.

Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S. J., & Fosso-Wamba, S. (2017). The role of Big Data in explaining disaster resilience in supply chains for sustainability. *Journal of Cleaner Production*, *142*, 1108–1118.

Perry, R. W. (2003). Incident management systems in disaster management. *Disaster Prevention and Management: An International Journal*, *12*(5), 405–412.

Rana, N. P., & Dwivedi, Y. K. (2015). Citizen's adoption of an e-government system: Validating extended social cognitive theory (SCT). *Government Information Quarterly*, *32*(2), 172–181.

Rana, N. P., Dwivedi, Y. K., Lal, B., Williams, M. D., & Clement, M. (2017). Citizens' adoption of an electronic government system: Toward a unified view. *Information Systems Frontiers*, *19*(3), 549–568.

Rana, N. P., Dwivedi, Y. K., Williams, M. D., & Weerakkody, V. (2016). Adoption of online public grievance redressal system in india: Toward developing a unified view. *Computers in Human Behavior*, *59*, 265–282.

Robillard, J., & Sambrook, R. C. (2008). USAF emergency and incident management systems: A systematic analysis of functional requirements. *White paper for United States Air Force Space Command Electronic Text at* http://www.uccs.edu/~rsambroo/Research/EIM_REQS.pdf 2008.

Shirani, A. I., Tafti, M. H., & Affisco, J. F. (1999). Task and technology fit: A comparison of two technologies for synchronous and asynchronous group communication. *Information & Management*, *36*(3), 139–150.

Shrivastava, S. K., Kumar, P., & Pandey, A. N. (2011). ibhugoal-bihar infrastructure mapping-geomatics oriented application model. *International Journal of Advanced Computer Engineering and Architecture*, *1*(1), 163–172.

Simon, H. A. (1997). The future of information systems. *Annals of Operations Research*, *71*, 3–14.

Sinha, A., & Kumar, P. (2016). A novel framework for social internet of things. *Indian Journal of Science and Technology*, *9*(36), 1–6.

Smith, W., & Dowell, J. (2000). A case study of co-ordinative decision-making in disaster management. *Ergonomics*, *43*(8), 1153–1166.

Son, J., Aziz, Z., & Pena-Mora, F. (2007). Supporting disaster response and recovery through improved situation awareness. *Structural Survey*, *26*(5), 411–425.

Straub, D., Boudreau, M. C., & Gefen, D. (2004). Validation guidelines for is positivist research. *Communications of the Association for Information Systems*, *13*(24), 380–427.

Thompson, C. W., & Hagstrom, F. (2008). Modeling healthcare logistics in a virtual world. *IEEE Internet Computing*, *12*(5), 100–104.

Tomaszewski, B. (2011). Situation awareness and virtual globes: Applications for disaster management. *Computers & Geosciences*, *37*(1), 86–92.

Turoff, M., Chumer, M., Van de Walle, B., & Yao, X. (2004). The design of a dynamic emergency response management information system (DERMIS). *JITTA: Journal of Information Technology Theory and Application*, *5*(4), 1.

Usoro, A., Shoyelu, S., & Kuofie, M. (2010). Task-technology fit and technology acceptance models applicability to e-Tourism. *Journal of Economic Development, Management, IT, Finance, and Marketing*, *2*(1), 1–32.

Van Wassenhove, L. N. (2006). Humanitarian aid logistics: Supply chain management in high gear. *Journal of the Operational Research Society*, *57*(5), 475–489.

Wang, J., Rosca, D., Tepfenhart, W., Milewski, A., & Stoute, M. (2008). Dynamic workflow modeling and analysis in incident command systems. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, *38*(5), 1041–1055.

Wang, J., Tepfenhart, W., & Rosca, D. (2009). Emergency response workflow resource requirements modeling and analysis. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *39*(3), 270–283.

Wang, X., Wu, Y., Liang, L., & Huang, Z. (2016). Service outsourcing and disaster response methods in a relief supply chain. *Annals of Operations Research*, *240*(2), 471–487.

Wetzels, M., Odekerken-Schroder, G., & van Oppen, C. (2009). Using PLS path modeling for assessing hierarchical construct models: Guidelines and empirical illustration. *MIS Quarterly*, *33*(1), 177–195.

Yang, L., Prasanna, R., & King, M. (2009). On-site information systems design for emergency first responders. *Journal of Information Technology Theory And Application*, *10*(1), 5–27.

Yang, L., Yang, S. H., & Plotnick, L. (2013). How the internet of things technology enhances emergency response operations. *Technological Forecasting and Social Change*, *80*(9), 1854–1867.

Yang, F., Yuan, Q., Du, S., & Liang, L. (2016). Reserving relief supplies for earthquake: A multi-attribute decision making of China Red Cross. *Annals of Operations Research*, *247*(2), 759–785.

Yen, D. C., Wu, C. S., Cheng, F. F., & Huang, Y. W. (2010). Determinants of users' intention to adopt wireless technology: An empirical study by integrating TTF with TAM. *Computers in Human Behavior*, *26*(5), 906–915.

Zigurs, I., & Buckland, B. K. (1998). A theory of task/technology fit and group support systems effectiveness. *MIS Quarterly*, *22*(3), 313–334.